Reciprocal influence of slow waves extracted in intracranial pressure, arterial pressure and cerebral blood velocity signals.

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Abstract: **Slow waves in intracranial pressure (ICP) and related signals seems of interest to evaluate the dynamic autoregulation, i.e. by comparison of the frequency links between an intracranial signal, e.g. ICP, cerebral blood velocity (CBV), and arterial blood pressure (ABP). To clarify the links, we compared two frequency methods based on coherence function to estimate the influence of ICP, ABP and CBV on couples, respectively CBV-ABP, ICP-CBV and ICP-ABP, of slow waves in the B and the UB bands. We found that B and UB waves activity in ICP, CBV and ABP had reciprocal influences, except for the UB activity in ICP-CBV link which seems to be less sensitive to ABP. These data confirmed the interest of to analyse the slow wave activity to evaluate dynamic autoregulation. The interest of taking into account the reciprocal influence of the signals must be evaluated.**
Keywords: **coherence function, partial coherence, slow waves, autoregulation, intracranial pressure**

I. INTRODUCTION

In intensive care unit, severe head injured patients are monitored with many tools informing on the biological status of pathophysiological mechanisms. Data are extracted from different biological signals, e.g. intracranial pressure (ICP), arterial blood pressure (ABP), cerebral blood velocities (CBV), cerebral perfusion pressure (CPP≈ ABP-ICP). The knowledge of autoregulation status, i.e. the capacity of the brain to maintain a relatively constant blood flow (CBV) in spite of CPP variations, is of interest but is less analysed and mainly by invasive methods.

The slow waves (e.g. pressure, velocity …) are present in physiological and pathophysiological conditions. First described by Janny [5] and Lundberg [11], they can be segmented in three bands : IB below 0.008 Hz, B]0.008; 0.05[Hz and UB]0.05; 0.2[Hz with the terminology introduced by Lemaire [9]. They seems to correspond to a vascular activity which is different function of the bands: B band is mainly dependant of the body vascular tree, and the UB band of a local vascular tree, as in the brain [4]. They can be used for the evaluation of the dynamic autoregulation by analysing the links between ICP and ABP slow B waves [6][10]. To determine the role of a third signal, on the links on couple of signals (ICP – ABP; ABP – CBV; CBV – ICP) we used two frequential methods: ordinary coherence and partial coherence.

II. METHODOLOGY

We recorded severe head injured patients function of the standard medical guidelines. Current medical transducers were used to collect data which were recorded with a software developed in our unit (URN) (sampling rate = 8 samp/sec). We computed results in off-line software in periods free of artefact. Each period had 34 min duration and was segmented in 8 blocks, with a frequential resolution of 3.9 mHz.. We investigated B and UB bands.

Coherence function. We can compare coherence function as a frequential correlation [1][3][12][13]. This function is based on the link between two signals for a given frequency. The function γ^2_{xy} for a couple (x, y) is based on spectral power S_{xx} :

$$\gamma^2{}_{xy} = \frac{\sum^{N} S_{xy} \times S_{xy}}{\sum^{N} S_{xx} \times \sum^{N} S_{yy}} \quad (1)$$

We computed coherence function for 3 couple of signals : (ICP, ABP), (ICP, CBV), (CBV, ABP). The value of the function evolves between 0, no link, and 1, one signal is the resultant of the other for a given frequency. We chose the frequency with the highest amplitude peak in the B and UB bands respectively FB, FUB.

Partial coherence was carried out following the methods of Bendat & Pierson [1][7][8][14]. The partial coherence was computed for FB and FUB. The partial coherence for a pair of signals (x and y_1) in relation to a third signal (y_2), resumed by (x, y_1)y_2 is obtained from the ordinary coherence of x and y_1 of which we removed the influence to a third signal (y_2).

Statistics. Values of coherence were tested using Student's t-test after a Fisher's z-transformation to obtain estimates with approximately normal distribution [13]. Only the data considered as statistically significant were accepted. A Bland and Altman test [2] was performed on the accepted data to provide limits of agreement between the two coherence methods. For each segment of data the difference of memberships was plotted against their mean value. The mean of the differences m and their standard deviation sd were then computed. The limit of agreement was admitted as 4 times the sd. We considered that if this limit was in order of the

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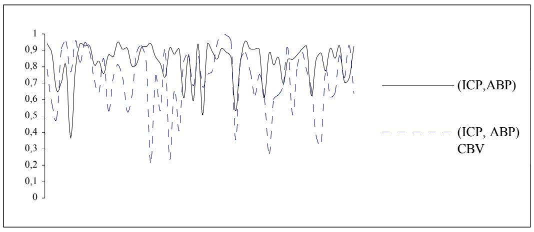
maximal value of the function, i.e. 1, then the results obtained by the two methods were different.

III. RESULTS

The partial and ordinary coherence were computed on 65 recorded periods. The mean values for the signals were: ICP (mmHg) = 16,35 ± 3,19, ABP (mmHg) = 100,19 ± 3,31, and CBV (arbitrary units) = 108,48 ± 59,81.

B band:

The mean value of FB were: ICP = 39,3 ± 11,2 mHz, CBV = 21,8 ± 11,5 mHz and ABP = 41,7 ± 9,9 mHz. The FB frequencies for ICP and ABP were very closed and high, in contrast to CBV's frequencies



which were lower.

Fig 1: (ICP, ABP) and (ICP, ABP)CBV representations

The mean values for (ICP,ABP) and (ICP, ABP)CBV were respectively: 0,82 ± 0,12 and 0,71 ± 0,19. The limit of agreement with Bland and Altman was 0.39. then we considered that ABP played a role in the link between ICP and CBV.

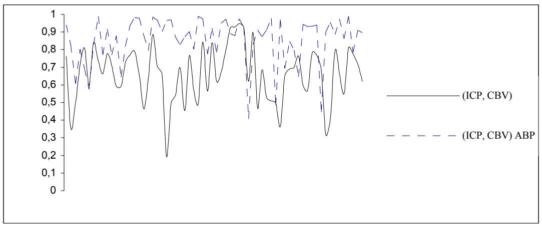


Fig 2: (ICP, CBV) and (ICP, CBV)ABP representations

The mean values for (ICP, CBV) and (ICP,CBV)ABP were respectively : 0,66 ± 0,15 and 0,85 ± 0,13. The limit of agreement with Bland and Altman was 0,39. then we considered that ABP played a role in the link between ICP and CBV.

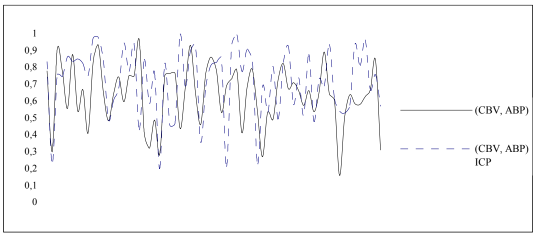


Fig 3: (CBV, ABP) and (CBV, ABP)ICP representations

The mean values for (CBV,ABP) and (CBV,ABP)ICP were respectively : 0,64 ± 0,17 and 0,71 ± 0,2. The limit of agreement with Bland and Altman was 0,44. then we considered that ICP played a role in the link between ABP and CBV.

UB band:

The mean value for FUB were for ICP = 74,4 ± 18,7 mHz; CBV = 108,1 ± 35,2 mHz and ABP = 81,6 ± 19,6 mHz. The frequency domain for ICP and ABP are closer than CBV domain.

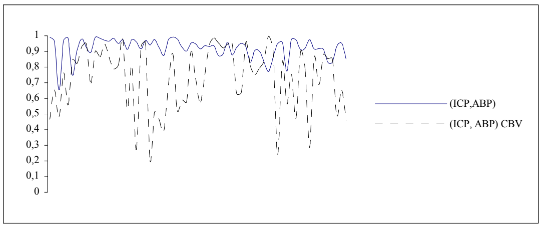


Fig 4: (ICP, ABP) and (ICP, ABP)CBV representations

The mean values for (ICP,ABP) and (ICP, ABP)CBV were respectively : 0,92 ± 0,06 and 0,73 ± 0,2. The limit of agreement with Bland and Altman was 0,43. then we considered that CBV played a role in the link between ICP and ABP.

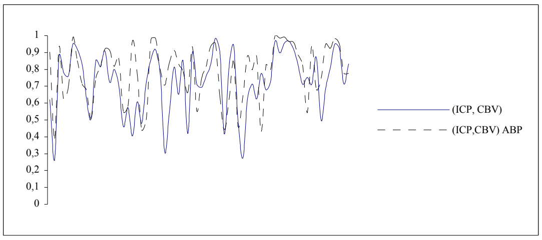


Fig 5: (ICP, CBV) and (ICP, CBV)ABP representations

The mean values for (ICP, CBV) and (ICP, CBV)ABP were respectively : 0,72 ± 0,18 and 0,78 ± 0,16 The limit of agreement with Bland and Altman was 0,31. then we considered that ABP played a role in the link between ICP and CBV.

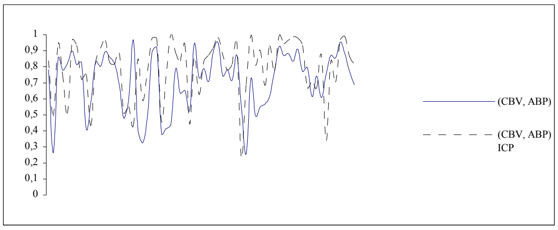


Fig 6: (CBV, ABP) and (CBV, ABP)ICP representations

The mean values for (CBV,ABP) and (CBV, ABP)ICP were respectively: 0,71 ± 0,18 and 0,79 ± 0,18. The limit of agreement with Bland and Altman was 0,38. then we considered that ICP played a role in the link between ABP and CBV.

In conclusion, in the B band, each signal influences links between the others. In the UB band we found the same influences, except for ABP which seemed to have no, or a low, influence on the links between ICP and CBV.

IV. DISCUSSION

In spite of the different mean values of FB and FUB for ICP, ABP and CBV, although ICP and ABP values are closed (for the two bands) we found influences, pondered function of the bands, between the signals. This suggest that the bands are the main elements, more than the frequencies, taking place in the links between the signals.

In the B band, the (CBV, ABP)ICP mean value is 19% upper the (CBV, ABP) mean value. Even if these values seem closed, the influence of ICP on this couple is not negligible and showed that ICP seems to play a role in the control of autoregulation, even out of intracranial hypertension conditions, as demonstrated by our data.

For (ICP,CBV)ABP, mean value is 22% most important than mean value of ordinary coherence. This could be explained by the strong biological link between the CBV and ABP, modulated by the cerebro-vascular resistances. This could also explained the difference between (ICP, ABP)CBV and (ICP,ABP).

UB band seems to represent a phenomena mainly local which could be illustrated by the fact that (ICP, ABP) was different of (ICP, ABP)CBV showing that a great part of this link is underlying by CBV. The influence of CBV is in order of 20% to the link between ICP and ABP. The comparison between (ICP, CBV) and (ICP, CBV)ABP suggested that ABP could play a poor role in the links of the UB waves. (the limit of agreement is the weakest of the six comparisons). It reinforces the idea about UB band.

Our results, concerning the different influences of ICP, also suggests that it seems to be necessary to include its analysis when autoregulation is evaluated, not only by slow waves analysis, by non–invasive methods, e.g. CBV versus ABP.

The differences between coherence functions, ordinary and partial, doesn't call into question the interest of the ordinary one. It only shows than we under or over estimate the degree of links but no the links themselves.

The explication on the poor influence of signals on the links could be explained by the existence of non-linear links, as evoked by Robertson [14].

V. CONCLUSION

Our results show the importance of the links, and their complexity, between the slow waves on different biological signals. The clinical implications of these data must be evaluated.

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